technical info

pco.edge

Camera Link Packing Modes

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This document describes the different packing modes for Camera Link of the pco.edge camera.

Target Audience: The information in this document is provided for technicians, engineers, and scientists.

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The cover photo shows an exemplary PCO camera system.
The lens is sold separately.

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Table of Contents

1 Purpose of the Packing

This document describes the different packing modes for Camera Link of the pco.edge camera. To take advantage of the full bandwidth of Camera Link in 10-TAP mode, the pixels are packed into special stream formats.

2 Camera Link Structure

The base Camera Link standard uses 28 bits to represent up to 24 bits or 3 taps of 8 bits of pixel data and 3 bits for Video Sync signals. These consist of Data Valid, Frame Valid, and Line Valid bits. The data is serialized 7:1, and the four data streams and a dedicated clock are driven over five LVDS pairs. The receiver accepts the four LVDS data streams and LVDS clock, and then drives the 28 bits and a clock to the board. The Camera Link standard calls for these 28 bits to be transmitted over 4 serialized differential pairs with a serialization factor of 7. The parallel data clock is transmitted with the data.

The Camera Link specification includes higher-bandwidth configurations that provide additional video data paths over a second connector/cable. The "Medium" configuration doubles the video bandwidth, adding additional 24 bits of data and the same 4 framing/enable signals as present in the "Base" configuration. The "Full" configuration adds another 16 bits to the data path, resulting in a 64 bit wide video path.

The “10-TAP” or also called “Basler Configuration” extends the width of the "Full" configuration by reassigning some of the redundant framing/enable signals to produce a data path width of 80 bits.

3 Camera Link 10-TAP

As described in chapter 3, Camera Link 10-TAP uses 80 bit per clock cycle. The Camera Link specification names each 8 bit port or also called tap from A to J. Figure 1 shows the distribution of the 10 taps over the 80 bits.

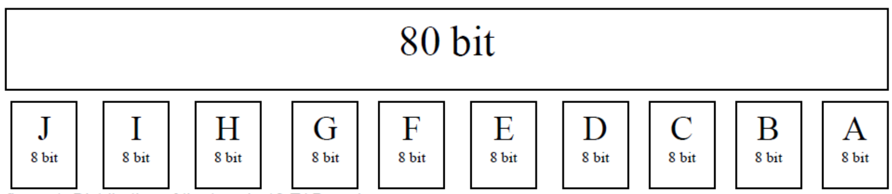

figure 1: Distribution of the taps in 10-TAP mode

The numbering of pixels in the camera always starts on the left side of the image to the right side. Figure 2 shows the counting of the pixels in one line.

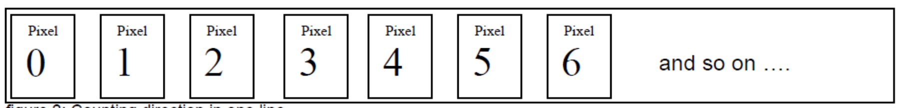

figure 2: Counting direction in one line

4 Packing

4.1 Pixel Value Alignment

The camera internally works with a Big Endian pixel structure. By using only less bits then available by the selected transfer mode, the most significant bits (MSB) are filled with zeros.

Examples:

a) Transfer Mode 16 Bit / Pixel Values 10 Bit

available bits: 16
used bits: 10
minimal value: 0x0000 (decimal: 0)
maximal value: 0x03FF (decimal: 1024)

b) Transfer Mode 12 Bit / Pixel Values 11 Bit

available bits: 12
used bits: 11
minimal value: 0x000 (decimal: 0)
maximal value: 0x7FF (decimal: 2047)

c) Transfer Mode 8 Bit / Pixel Values 8 Bit

available bits: 8
used bits: 8
minimal value: 0x00 (decimal: 0)
maximal value: 0xFF (decimal: 255)

4.2 Packing of 16 bit

When using 16 bits per pixel, each pixel needs 2 taps to be transferred. So in each clock cycle 5 pixels are sent from the camera to the grabber. Counting from left to right the camera generates the in figure 3 shown streams.

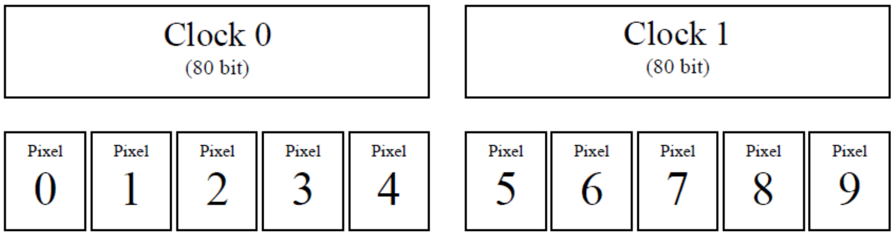

figure 3: Internally generated data packages

Most grabber manufactures (SiliconSoftware, Bitflow, etc.) interpret the pixels in the Camera Link data stream from right to left. For this reason the sequence of the 5 pixels in one 10-TAP package is switched backwards (figure 4). This is the most efficient way to transfer 16 bit pixels over Camera Link.

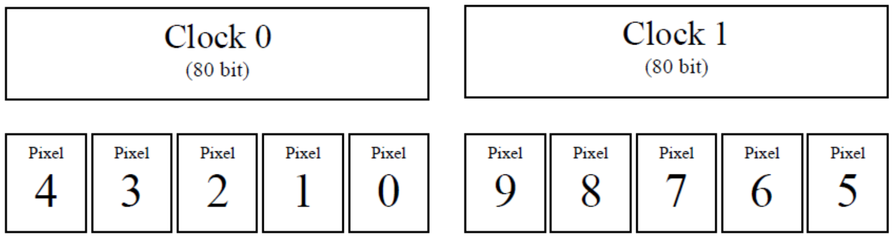

figure 4: 80 bit packages send over Camera Link

4.3 Packing of 12 bit

In case of transferring 12 bits per pixel, the camera needs 3 clock cycles to send 20 pixels to the grabber (figure 5). Each data package contains 6 full and fractional pixels.

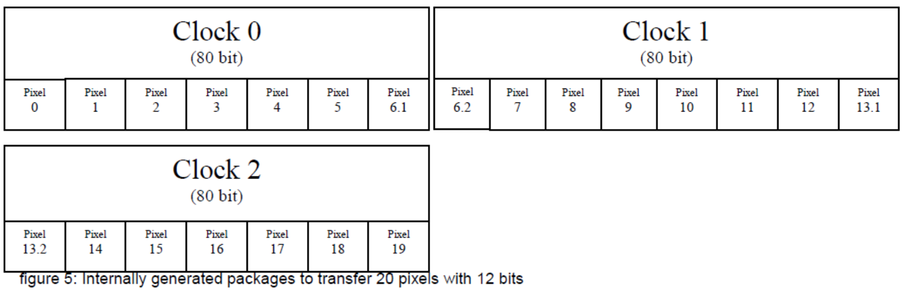

figure 5: Internally generated packages to transfer 20 pixels with 12 bits

The generated data stream has to be send over the existing Camera Link structures in the camera. So the internally generated 80 bit data stream is matched into five 2 byte blocks (16 bit) and switched backwards as described in figure 4.

4.4 Packing of 8 bit

When using 8 bits per pixel, each pixel needs 1 taps to be transferred. In this case each clock cycle contains 10 pixels. Counting internally from left to right the the Camera Link specification is numbering the bits from the other side. So the bits are switched before transferred over Camera Link (figure 6).

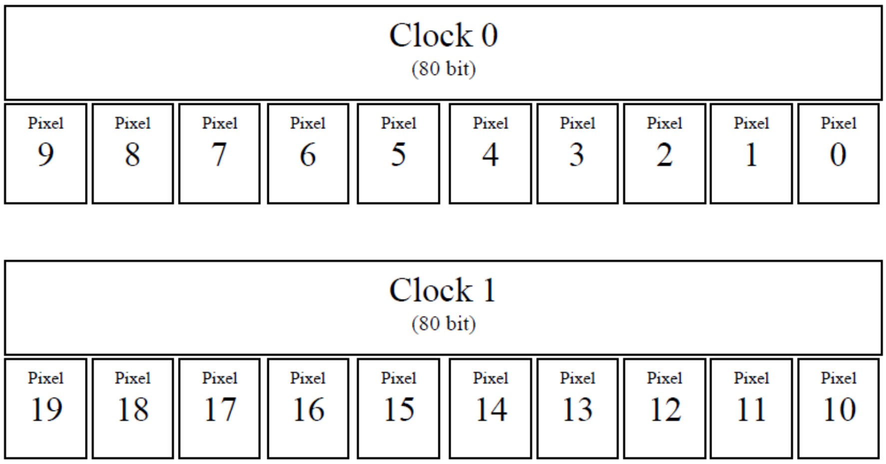

figure 6: : 80 bit packages send over Camera Link

5 Examples

5.1 Packing 16 bit

Pixel Value Counting 0 to 15

a) Internal generation

Clock Cycle 0	0000	0001	0002	0003	0004
Clock Cycle 1	0005	0006	0007	0008	0009
Clock Cycle 2	000A	000B	000C	000D	000E

b) Data stream after 16 bit switch

Clock Cycle 0	0004	0003	0002	0001	0000
Clock Cycle 1	0009	0008	0007	0006	0005
Clock Cycle 2	000E	000D	000C	000B	000A

5.2 Packing 12 bit

Pixel Value Counting 0 to 19

a) Internal generation

Clock Cycle 0	0000 0100 2003 0040 0500
Clock Cycle 1	6007 0080 0900 A00B 00C0
Clock Cycle 2	0D00 E00F 0100 1101 2013

b) Data stream after 16 bit switch

Clock Cycle 0	0500 0040 2003 0100 0000
Clock Cycle 1	00C0 A00B 0900 0080 6007
Clock Cycle 2	2013 1101 0100 E00F 0D00

Pixel Value 2047

a) Internal generation

Clock Cycle 0	7FF7 FF7F F7FF 7FF7 FF7F
Clock Cycle 1	F7FF 7FF7 FF7F F7FF 7FF7
Clock Cycle 2	FF7F F7FF 7FF7 FF7F F7FF

b) Data stream after 16 bit switch

Clock Cycle 0	FF7F 7FF7 F7FF FF7F 7FF7
Clock Cycle 1	7FF7 F7FF FF7F 7FF7 F7FF
Clock Cycle 2	F7FF FF7F 7FF7 F7FF FF7F

6 Storing Data

The last capitals described how the pco.edge sends the data over Camera Link to the grabber. The way the grabber interprets the data is controlled by software. Most grabbers have on board memory to store the data internal. After that it is transferred over the computer bus (e.g. PCIe) with a DMA or by CPU into the computer memory. The structure of stored data depends on many factors:

- computer system
- memory access (e.g. 32bit, 64bit)
- grabber properties
- drivers
- etc.

7 Source Code Example

The following source code is a typical example. It shows how one line 12 bit data can be encoded to 16 bit data:

```
int x,y,off;
        DWORD *picadr_in;
        DWORD *picadr_out;
        DWORD *lineadr_in;
        DWORD *lineadr_out;
        DWORD a;

        picadr_in=(DWORD *)bufadr;
        picadr_out=(DWORD *)bufent->bufadr;
        off=(entry->act_width*12)/32;
        lineadr_in=picadr_in;//+y*off;
        lineadr_out=picadr_out;//+y*entry->act_width;

        for(x=0;x<off;)
        {
          a = (*lineadr_in&0x0000FFF0)>>4;
          a|= (*lineadr_in&0x0000000F)<<24;
          a|= (*lineadr_in&0xFF000000)>>8;
          *lineadr_out=a;
          lineadr_out++;

          a = (*lineadr_in&0x00FF0000)>>12;
          lineadr_in++;
          x++;
          a|= (*lineadr_in&0x0000F000)>>12;
          a|= (*lineadr_in&0x00000FFF)<<16;
          *lineadr_out=a;
          lineadr_out++;
          a = (*lineadr_in&0xFFF00000)>>20;
          a|= (*lineadr_in&0x000F0000)<<8;
          lineadr_in++;
          x++;
          a|= (*lineadr_in&0x0000FF00)<<8;
          *lineadr_out=a;
          lineadr_out++;
          a = (*lineadr_in&0x000000FF)<<4;
          a|= (*lineadr_in&0xF0000000)>>28;
          a|= (*lineadr_in&0x0FFF0000);
          *lineadr_out=a;
          lineadr_out++;
          lineadr_in++;
          x++;
         }
```

maximize the moment

PCO AG was founded in 1987. The company headquarters in Kelheim employs more than 50 specialists in the development and production of optimized, fast, sensitive camera systems for scientific applications. PCO's range of products includes digital camera systems featuring high dynamics, extremely high sensitivity, high resolution, high speed, and extremely low noise, which are sold in industrial and scientific markets all over the world.

Cameras for every point of view.

The systems produced by PCO AG are cameras and scientific measuring instruments at the same time. Our high-tech systems are mostly the result of manual labor: over 50 highly specialized employees handle development and production at the Kelheim site. We deliver roughly 4.000 cameras a year to customers all over the world. As in every cutting edge technology, dialogue with the user is the main focus of PCO's approach. Worldwide representatives, in cooperation with the in-house marketing division and technical support team, ensure that PCO camera systems are developed in step with the individual requirements of our customers.

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